GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT INITIATION

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Date: October 20, 1976

Project Title: Two-Dimensional Optical/Digital Signal Processing

Project No: E-21-689

Project Director: Dr. William T. Rhodes

Sponsor: U. S. Army Research Office; Research Triangle Park, NC 27706

Agreement Period: From 10/15/76 Until 1/14/78

Type Agreement: Grant No. DAAG29-76-G-0340

Amount: $48,608 ARO
10,308 GIT (E-21-347)
$58,916

Reports Required: Progress Report
Technical (when justified
Final Report

Sponsor Contact Person (s):

Technical Matters	Contractual Matters (thru OCA)
Electronics Division U.S. Army Research Office P.O. Box 1211 Research Triangle Park North Carolina 27706	Chief, Procurement Office U.S. Army Research Office P.O. Box 1211 Research Triangle Park North Carolina 27706

Defense Priority Rating: None

Assigned to: Electrical Engineering (School/Laboratory)

COPIES TO:

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CA-3 (3/76)

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SPONSORED PROJECT TERMINATION

Date: 2/17/78

Project Title: Two- Dimensional Optical/Digital Signal Processing

Project No: E-21-689

Project Director: Dr. William T. Rhodes

Sponsor: U.S. Army Research Office; Research Triangle Park, NC 27706

Effective Termination Date: 1/14/78

Clearance of Accounting Charges: 1/14/78

Grant/Contract Closeout Actions Remaining:

_ Final Invoice and Closing Documents
X Final Fiscal Report and Closing Documents
_ Final Report of Inventions
X Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other ______

NOTE: SEE E-21-B00

Assigned to: Electrical Engineering (School/Laboratory)

COPIES TO:

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EES Information Office
Project File (OCA)
Project Code (GTRI)
Other ______

CA–4 (3/76)

E-21-689

PROGRESS REPORT

1. ARO PROPOSAL NUMBER: 14572EL

2. PERIOD COVERED BY REPORT: 15 October 1976 - 30 June 1977

3. TITLE OF PROPOSAL: Two-Dimensional Optical/Digital Signal Processing

4. CONTRACT OR GRANT NUMBER: DAAG29-76-G-0340

5. NAME OF INSTITUTION: Georgia Institute of Technology

6. AUTHOR OF REPORT: Dr. William T. Rhodes, Assoc. Prof. Elect. Engrng.

7. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP DURING THIS PERIOD, INCLUDING JOURNAL REFERENCES:

   (1) "Bipolar Pointspread Function Synthesis by Phase Switching," Applied Optics, Vol. 16, pp. 265-267 (1977).

   (2) "Two-Pupil Synthesis of Optical Transfer Functions," to be published in Applied Optics; with A. W. Lohmann.

   (3) "Incoherent Imaging and Source Size: A Fourier Optics Approach," submitted for publication in the Journal of the Optical Society of America.

   (4) "Non-Coherent Optical Processing with Two-Pupil Hybrid Systems," to be published in the Proceedings of the 1977 International Optical Computing Conference, San Diego, 23-26 August 1977.

   (5) "1-D to 2-D and 2-D to 1-D Mappings in Optical Signal Processing," to be published in the Proceedings of the Symposium/Workshop on Effective Utilization of Optics in Radar Systems, Huntsville, Alabama, 27-29 September 1977.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIE REPORTING PERIOD:

   Dr. William T. Rhodes (Principal Investigator)

   Mr. James M. Florence, Ph.D. candidate.

14572EL

DR. WILLIAM T. RHODES
GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GA 30332

I. Hybrid Incoherent Optical Spatial Filtering

Coherent spatial filtering systems have seen extensive development during the past decade because of their conceptual simplicity. Incoherent S-F systems are less simple conceptually and are limited in their direct implementation to non-negative signal processing operations. Nonetheless, the incoherent systems offer significant advantages: higher spatial resolution; they operate with a wider range of inputs (e.g., printed matter, CRT displays, etc.); positioning tolerances are much less critical; greater flexibility in manufacture of pupil plane filter transparency; redundancy improves signal-to-noise characteristics. We have written definitive paper (Ref. (2)) on the synthesis of bipolar spatial impulse responses with two-pupil hybrid systems and investigated tradeoffs for different kinds of two-pupil systems (Ref. (4)). Bipolar impulse response increases applicability of incoherent processing systems substantially. Basic system for a particular approach (Ref. (1)) has been researched and development of experimental system partially completed.

Theoretical analyses have lead to significant improvements in conceptual understanding of incoherent optical imaging and spatial filtering systems (Ref. (3)) and to techniques for reducing noise and aliasing errors in incoherent spatial filtering systems that use computer-generated holograms for pupil transparencies (paper completed, not yet submitted for publication). All of this work provides a solid basis for experimental effort to begin later this year. Applicability to high-speed parallel processing of imagery and other 2-D signals; especially appropriate to hybrid configurations.

II. 1-D to 2-D and 2-D to 1-D Mappings in Optical and Hybrid Signal Processing

Preliminary work in this area has lead to two significant ideas currently being developed (Ref. (5)):

(1) Use of 2-D to 1-D mappings in shift-variant image processing. With NSF support we have developed optical techniques for shift-variant processing of 1-D signal information. By optically converting a 2-D image to a 1-D format, we can apply these techniques, then map back to a final 2-D format for display. General space-variant operations can be performed in parallel on imagery of reasonably large spacebandwidth product. Potential applicability to image processing where imaging system is space-variant.

(2) Use of heterodyne optical signal processing and 2-D Fourier transform of raster recorded signals in the recording and display of non-framing video information. The 2-D display scene evolves continuously in time, with fully adjustable bandwidth (time constant). Potential applicability to radar display systems. Limited experimental work now beginning.

ABSTRACTS OF PAPERS

"Bipolar Pointspread Function Synthesis by Phase Switching" (1)

Bipolar pointspread functions for incoherent spatial filtering can be synthesized using a phase switching method similar to that used in radio astronomy. The method is attractive for two principal reasons: (1) it is technologically well suited to high speed implementation, and (2) a nearly arbitrary synthesis can be effected using easily fabricated zero-order positive-real filter transparencies. Further, bias noise is easily minimized. A general analysis is presented, including a discussion of filter transparency specification.

"Two-Pupil Synthesis of Optical Transfer Functions" (2)

Incoherent optical spatial filtering systems have a number of advantages over their coherent counterparts; however, they are limited in their conventional form to operating with nonnegative-real input, output, and pointspread distributions. Most serious is the limitation to nonnegative-real impulse responses. A broad class of hybrid methods is investigated that employs two pupils in the synthesis of bipolar-real impulse responses. The mathematical structure of these syntheses is presented along with limitations in the presence of various constraints. Minimization of image plane bias is considered. Methods for implementation are described and categorized.

"Incoherent Imaging and Source Size: A Fourier Optics Approach" (3)

A simple condition on the illuminating source is presented that must be satisfied if a transilluminated object is to be imaged incoherently. The condition is obtained using a Fourier optics treatment of an imaging system and is thus particularly useful in the context of optical information processing applications. Only light amplitude and irradiance distributions are involved in the analysis. The approach is conceptually appealing, having a convenient physical interpretation. Critical considerations are the size of the pupil plane aperture and the spatial extent in the pupil plane of the Fourier transform (Fraunhofer pattern) of the object transparency.

"Non-Coherent Optical Processing with Two-Pupil Hybrid Systems" (4)

Recent developments in non-coherent optical processing suggest that hybrid incoherent optical/electronic systems present a viable alternative to coherent optical systems for diffraction-limited parallel processing of two-dimensional signals. Favorable characteristics of incoherent systems include greatly simplified input transducer requirements and a redundancy or multichannel nature that makes them resistent to the blemish noise typical of coherent processors. In this paper we discuss two classes of hybrid optical/electronic methods for bipolar processing of two-dimensional signals using two-pupil optical systems: direct subtraction methods and carrier methods. Tradeoffs and limitations are considered, and a new method for realizing a general bipolar pointspread function with positive-real pupil transparencies is presented.

"1-D to 2-D and 2-D to 1-D Mappings in Optical Signal Processing" (5)

The two-dimensionality of optical processing systems, both coherent and incoherent, can be explo ted in many ways in the processing of one-dimensional signal information. For example, spectral analysis of temporal signals with time-bandwidth product in excess of 10^6 can be performed optically if the signal is presented to the optical system in a raster format. The two-dimensionality of an optical system can also be expoloted to perform operations on one-dimensional signals that are space-variant or frequency-variant. In this paper we present a number of basic ideas regarding the use of 1-D to 2-D and 2-D to 1-D mappings in optical information processing and discuss their application to radar signal processing. Included are discussions of direction finding with large time-bandwidth product signals, time-frequency domain signal processing, general space-variant processing of two-dimensional signals, and a novel optical heterodyne method for mapping two-dimensional spatial signals into one-dimensional temporal signals that can be easily converted to a continuous update display.

E-21-689

FINAL REPORT

Contract No.: DAAG29-76-G-0340

Title: "Two-Dimensional Optical/Digital Signal Processing"

Principal Investigator: W. T. Rhodes

Research during this period concentrated in two areas: (1) hybrid incoherent optical spatial filtering and (2) 1-D to 2-D and 2-D to 1-D mappings in optical and hybrid optical digital signal processing. Principal motivation has been the development of greater compatibility between optical computing systems and digital signal processing systems for two-dimensional information. Considerable theoretical work has been done in the incoherent image processing area and extensive instrumentation set up for later experimental efforts. Preliminary theoretical and experimental work has been done in the area of signal mappings; more detailed investigations are to follow.